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The Oklo Phenomenon: A history of Nuclear Reactors Two Billion Years in The Making

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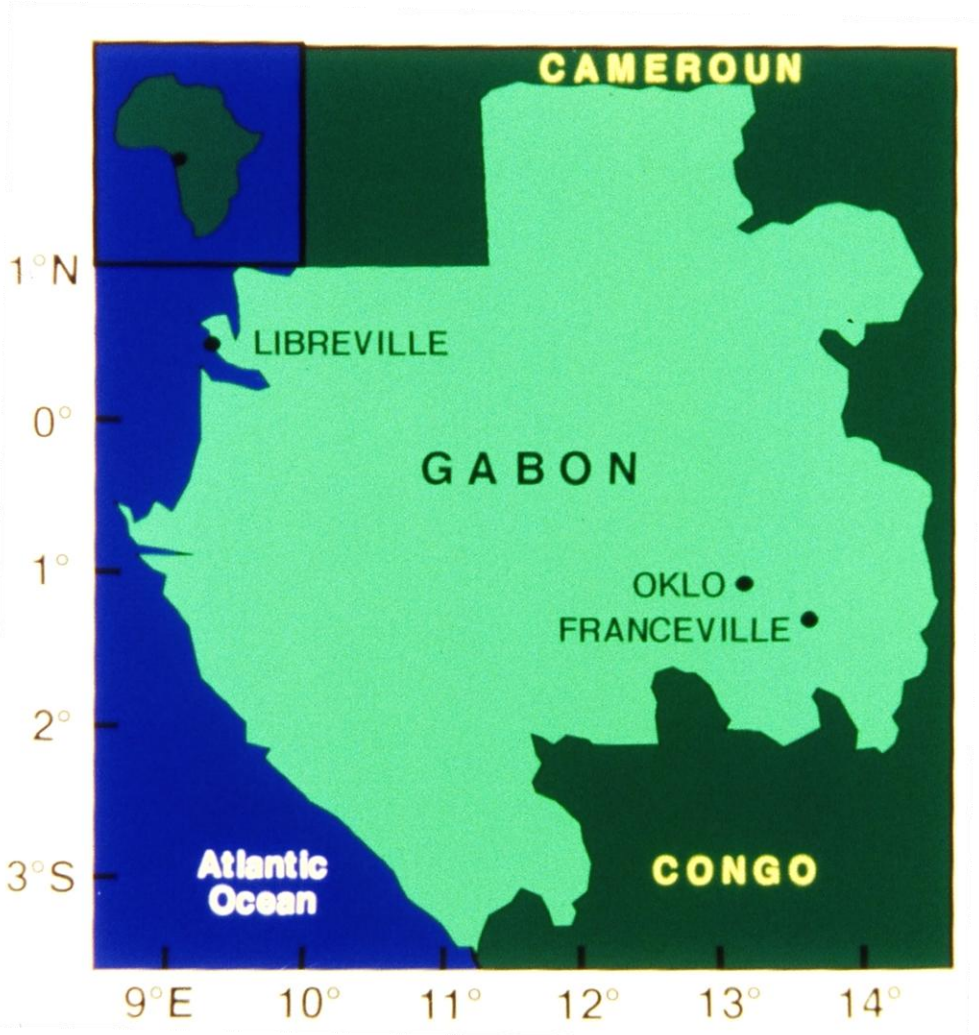
Geography of Gabon



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People of Gabon

Environs of Gabon

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Critters of Gabon

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Consequences of Critter Encounters...

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A Brief History of the Geology and Formation of the Oklo Ore Deposit and Natural Nuclear Reactors

- Francevillian Basin Formation and deposition of the Francevillian sedimentary series 2.1 Ga.
  - O2 levels in the earths atmosphere are rising
  - Early life (Prokaryotes) are active in the earth's oceans
- Formation of the Oklo Ore Deposit and Natural Fission Reactors 1.97 Ga.
- Reactors operate intermittently over a period of several hundred years and shut down.
- Basin undergoes little change over its two billion year history.

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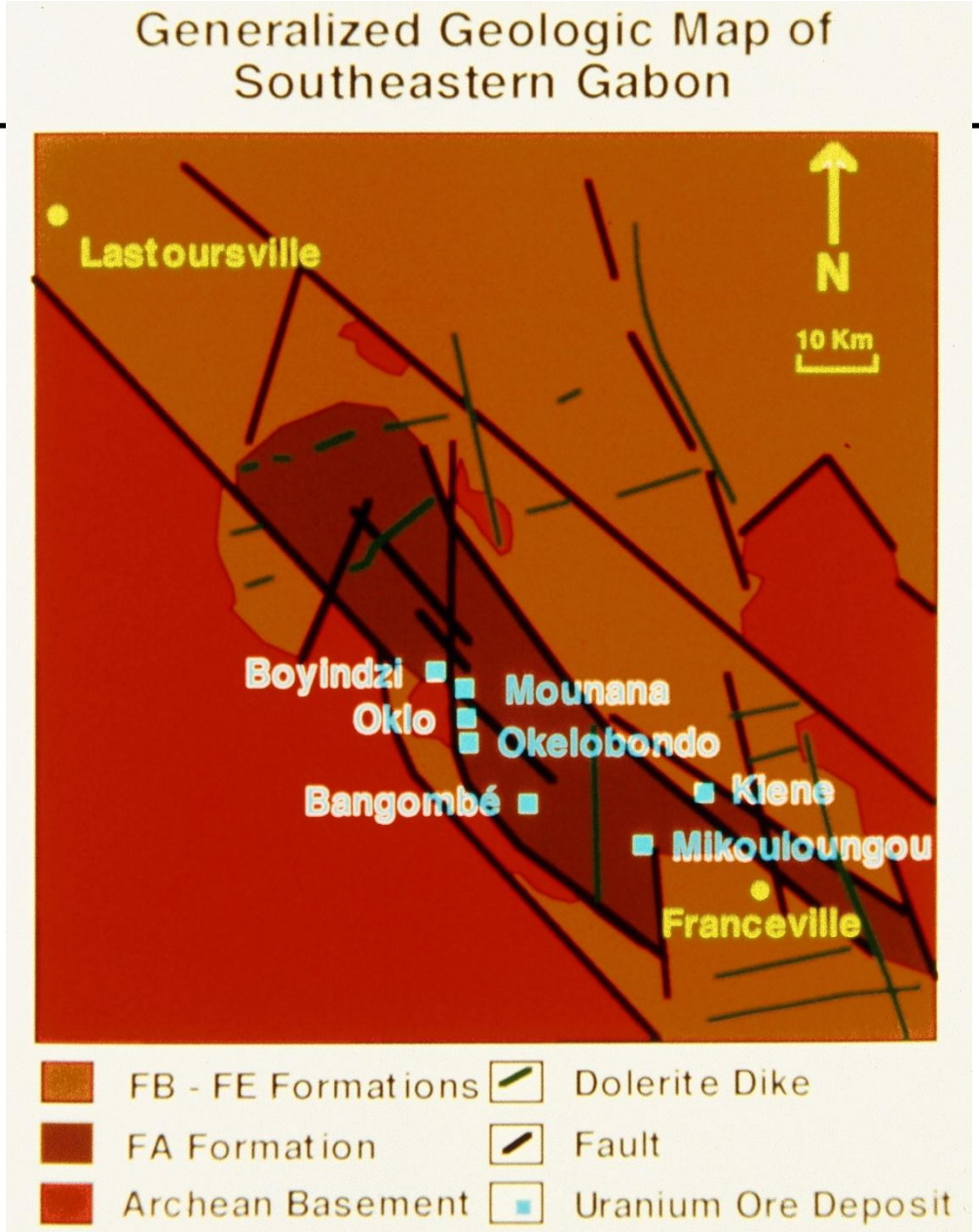
Geology of the Oklo Ore Deposit



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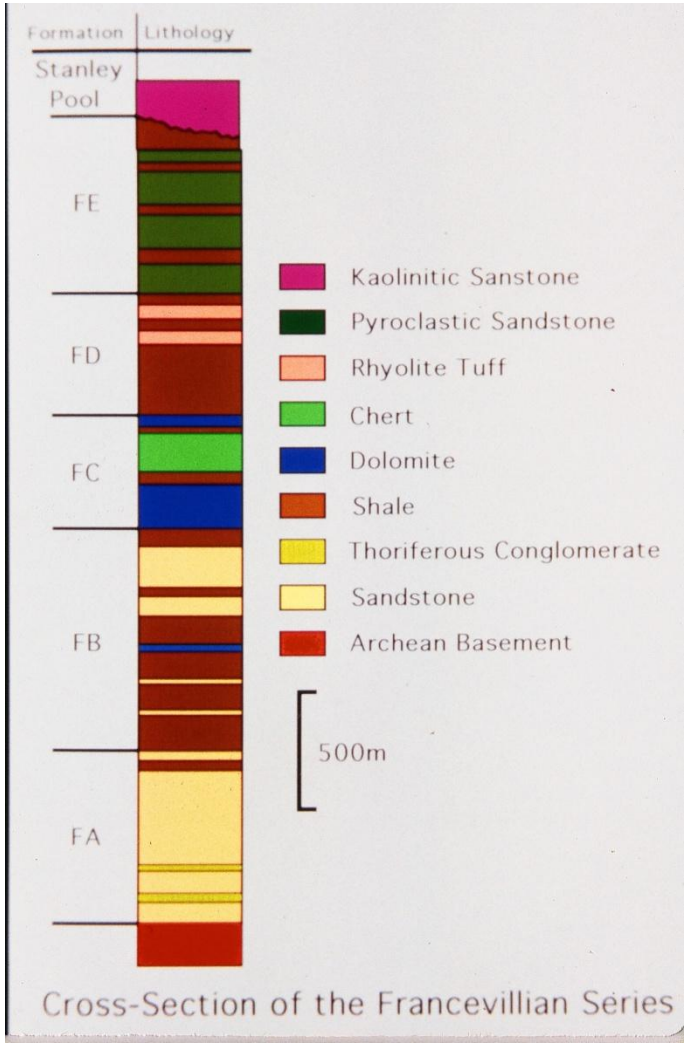
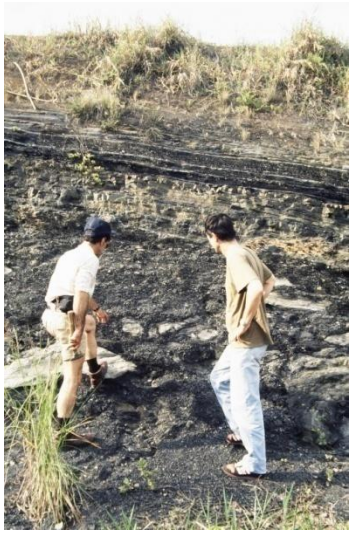
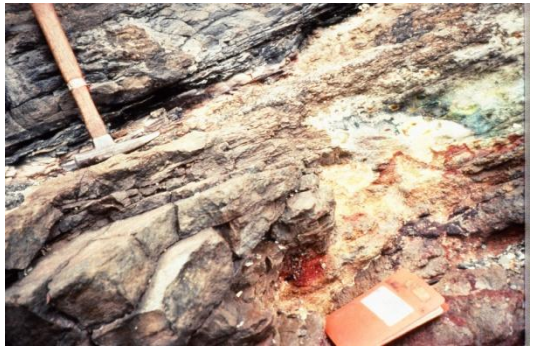
Geology of the Oklo Ore Deposit



Cross-Section of the Francevillian Series





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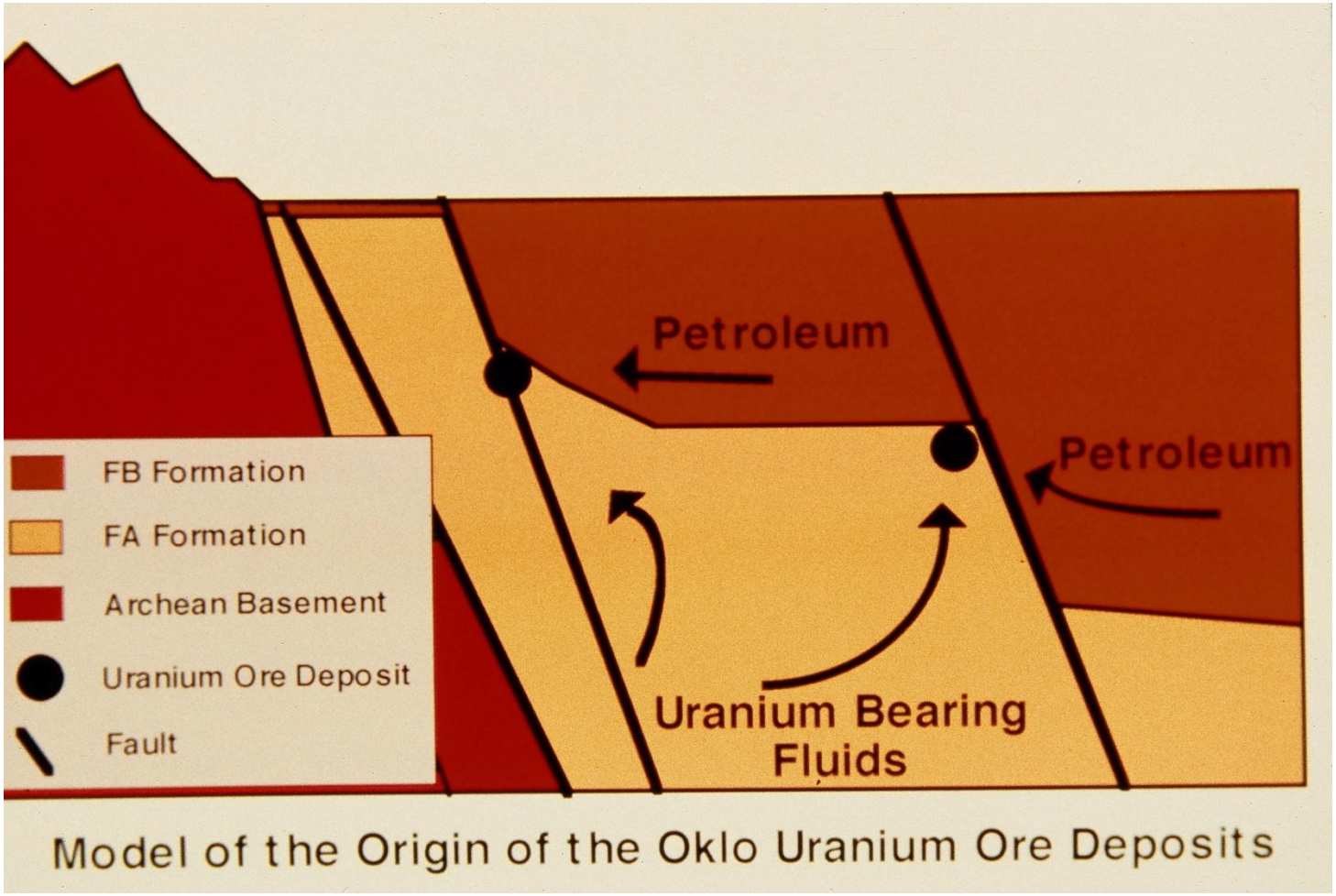
Geology of the Oklo Ore Deposit



Model of the Origin of the Oklo Uranium Ore Deposits

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Geology of the Oklo Ore Deposit

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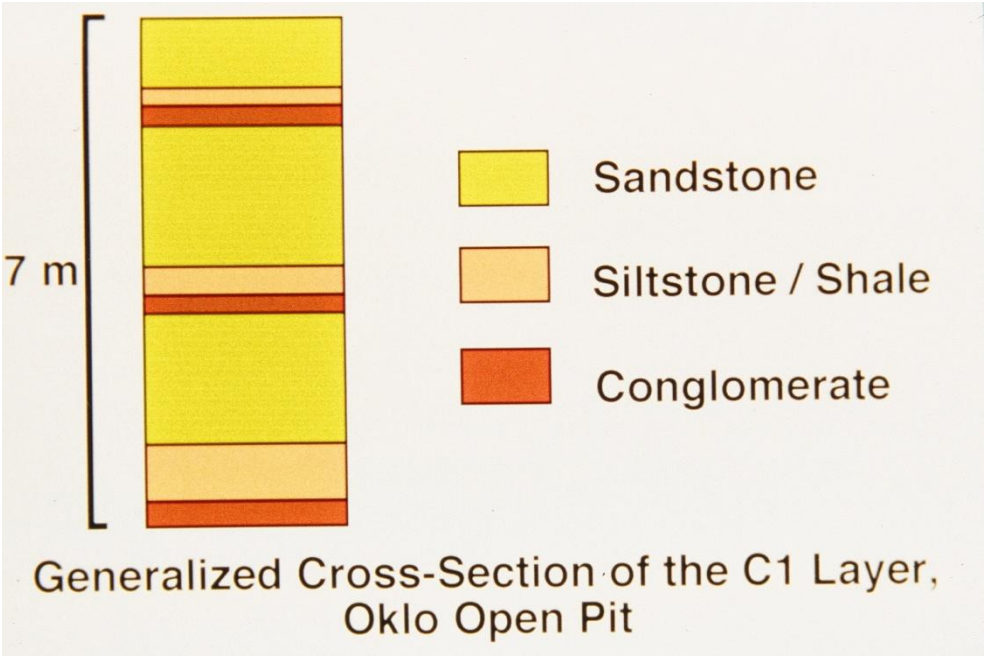
Geology of the Oklo Ore Deposit



Generalized Cross-Section of the C1 Layer, Oklo Open Pit

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Conditions Required For Formation of a Natural Reactor

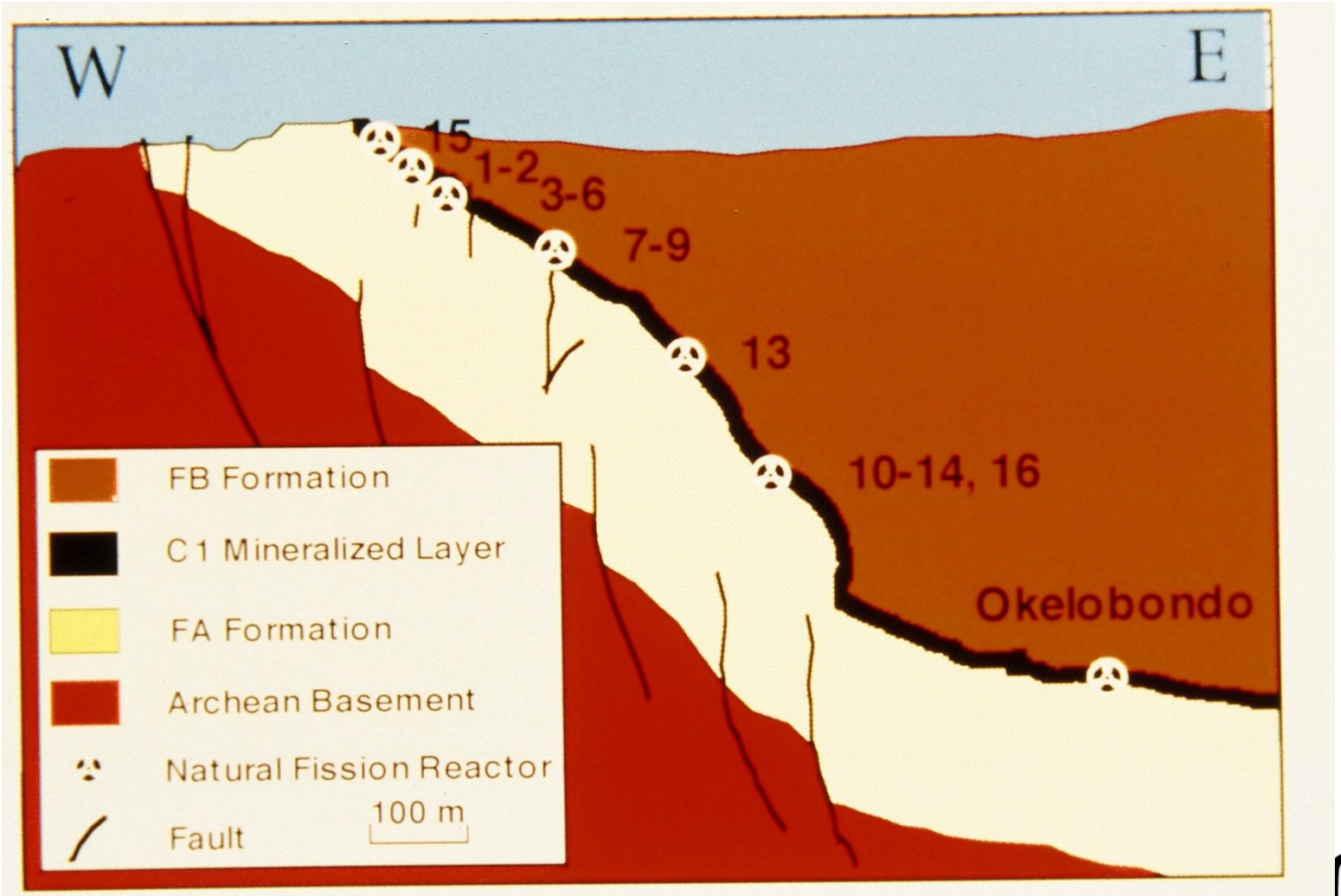
- High concentrations of fissionable U235
  - Concentration of U235 at Oklo was >3%
  - UO2 concentrations average 20-60% in the reactor zones
- Absence of significant quantities of neutron poisons (Boron, Lithium, etc.)
- Fractured and porous rock to enable water circulation and the deposition of large quantities of uranium in lens shaped geometries.

Conditions Required For Formation of a Natural Reactor

- Presence of a neutron moderator (water, hydrocarbons?) to ‘thermalize’ or slow neutrons to enhance absorption by U nuclei.

- Sustained operation is enabled by the formation of fissionable Pu 239
  - As much as 45% of the fuel consumed was produced by the decay of Pu239.

Geology of a Natural Reactor



chematic Cross-Section of the Oklo and Okelobondo Ore Deposits

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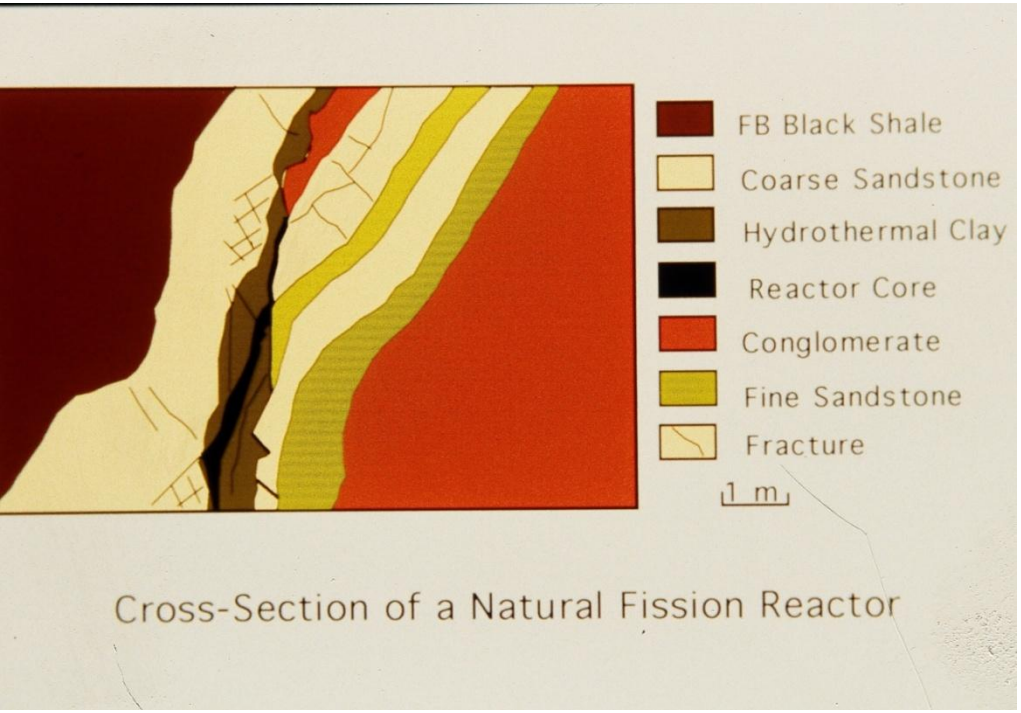
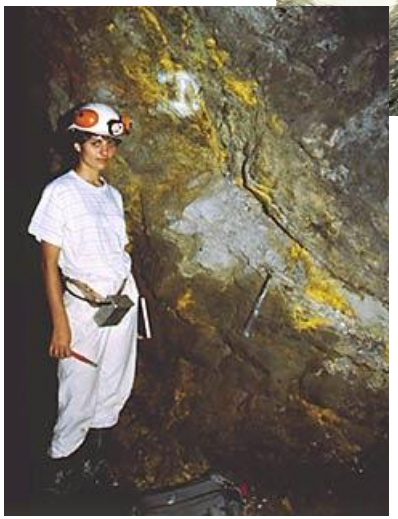
Geology of a Natural Reactor





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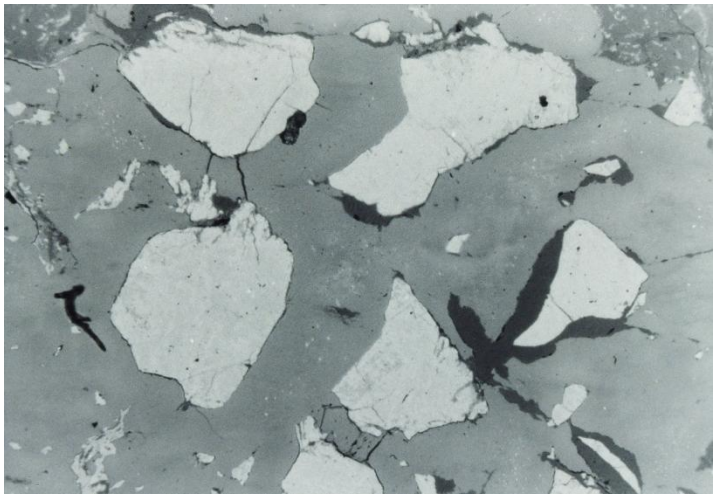
Geology of a Natural Reactor



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Characteristics of Reactors 1-6

- Generally little or no carbonaceous matter
- Reactor zones are generally devoid of silica; entirely replaced by clay minerals.
- Reactors ran hotter, several samples show very significant U depletions.
- Little of the common Sr, Cs, Rb, Ba fission products retained. Good retention of actinides and REE FPs; many others present as well.

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Characteristics of Reactors 7-9, 10

Abundant organic matter

Some silica present (zone 9)

Reactors operate at lower temperatures U235 depletions are smaller.

Increased retention of the common and relatively mobile Sr, Cs, Rb, Ba fission products and in general better for all FPs.

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Characteristics of Other Reactors

Abundant organic matter in reactor 10 creates very reducing conditions in the core resulting in the formation of metallic lead and copper.

Reactors 10 and 13 are close to a dolerite dike intrusion (~700Ma). Both show perturbations in uranium lead ratios indicating hydrothermal disturbance.

Bangombe reactor is a few meters from the surface and is undergoing intense weathering under the current equatorial climate conditions. Uranium is being remobilized; depleted U in the core is replaced by normal U yet fission REE products remain.

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Current Activities

- **Mines are shut down, COMUF is no more; little opportunity to discover new reactors.**
- **Most of the French CNRS samples are stored at an AREVA facility due to safety concerns.**
- **Little active research on reactor samples but some modeling and other activities do continue (Mishkin, Gauthier-Lafaye and a few others).**